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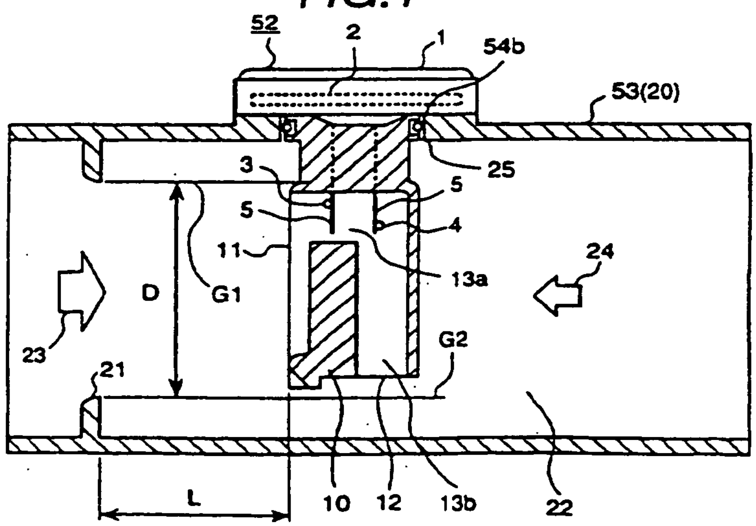
(54) **Heating resistor type air flow meter**

(57) A heating resistor type flow meter is provided. The meter comprises a main air flow passage body 20 forming a main air flow passage for allowing air flowing therethrough; and a measuring module 52 having a heating resistor for measuring a flow rate of the air, inserted inside the main air flow passage body, wherein the measuring module comprises the heating resistor 3 inside an auxiliary air flow passage body forming an L-shaped auxiliary air flow passage having an inlet opening 11 and an outlet opening portion 12; the main air flow passage body comprises an annular constriction 21 on a periphery of the inner side wall positioned in an upstream side of the air flow passage body; and both of the inlet opening portion and the outlet opening portion are arranged within a flow flux zone inside the diameter "D" of the constriction 21.

FIG.1



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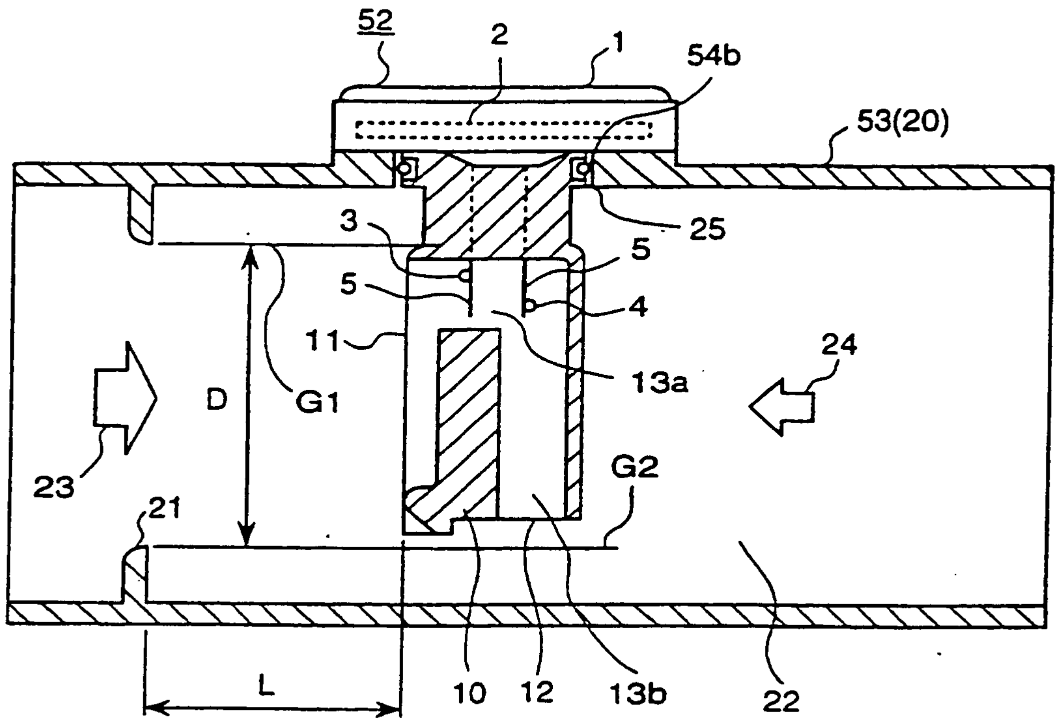

52
2
1
54b
53(20)
3
25
5
5
4
11
13a
24
D
G1
23
G2
21
22
L
10
12
13b

FIG.1

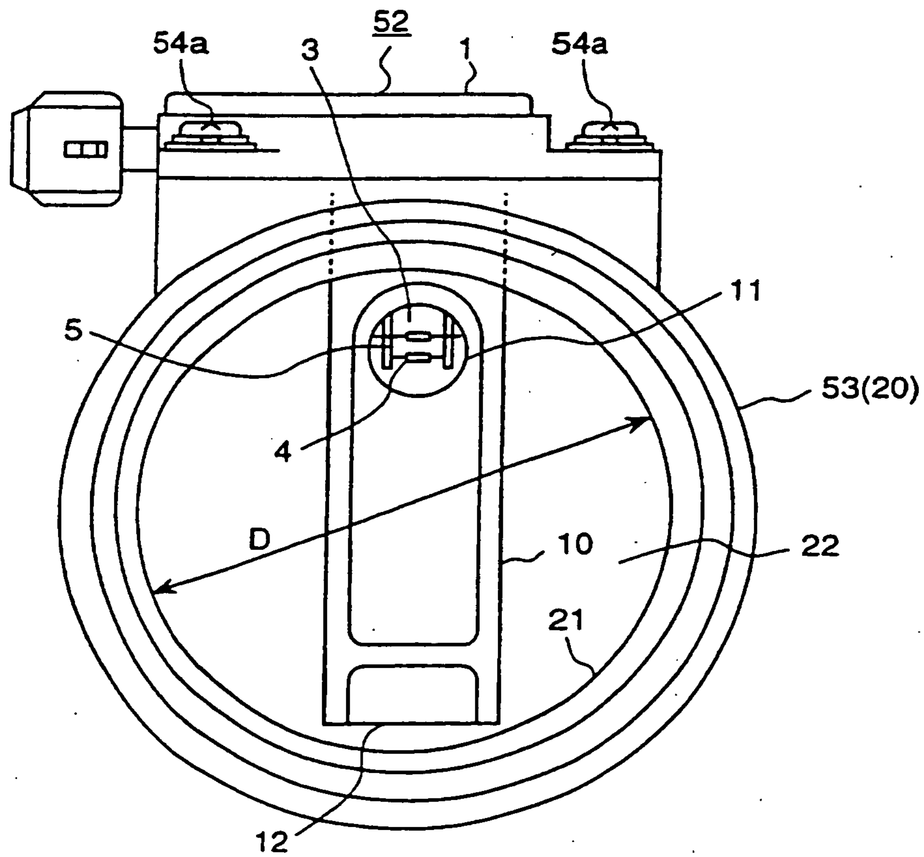

54a
52
3
1
54a
11
5
53(20)
4
D
10
22
21
12

FIG.2

FIG.3

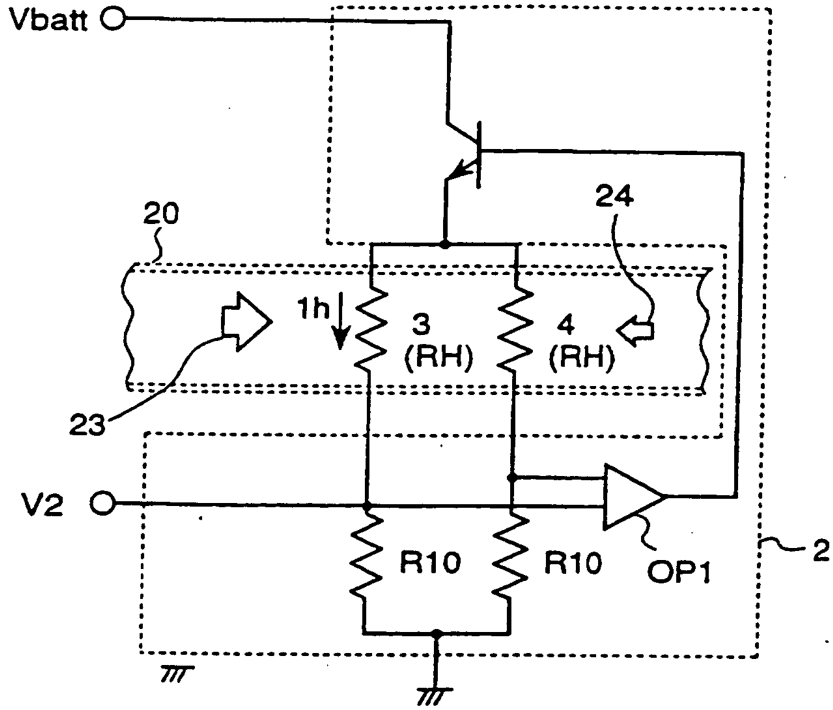


FIG.4A

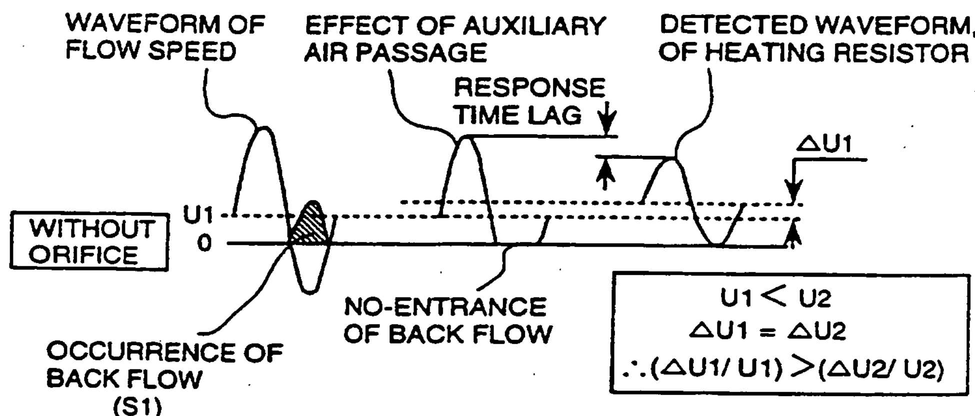


FIG.4B

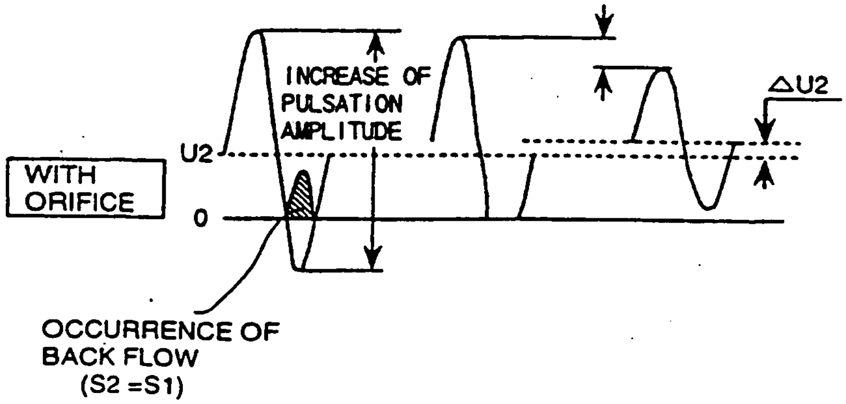


FIG.5A

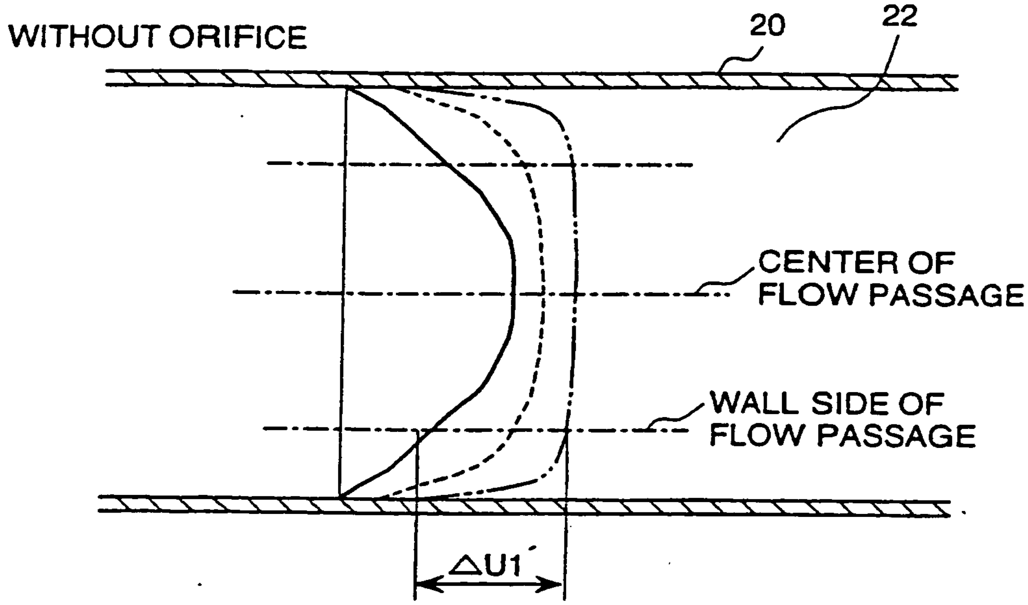

WITHOUT ORIFICE
20
22
CENTER OF FLOW PASSAGE
WALL SIDE OF FLOW PASSAGE
△U1´

FIG.5B

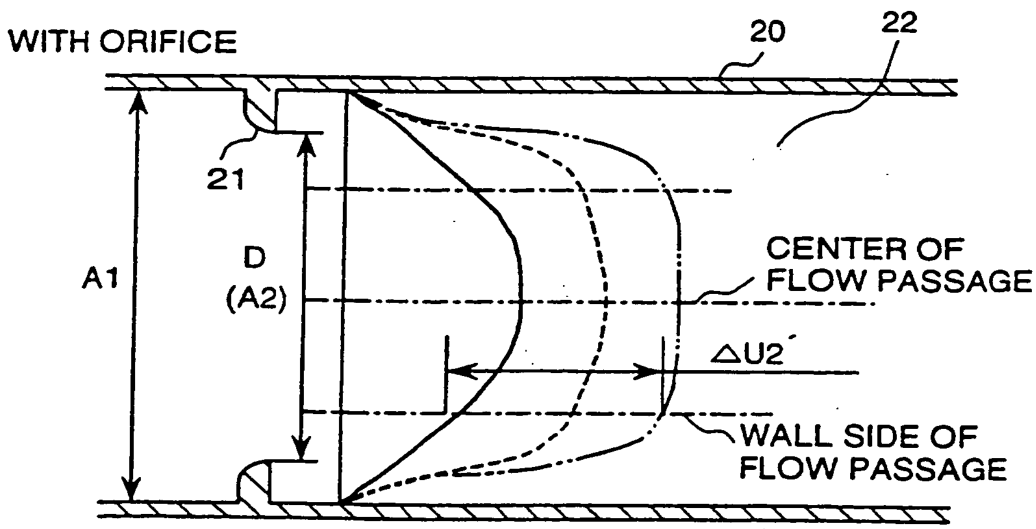

WITH ORIFICE
20
22
21
A1
D (A2)
CENTER OF FLOW PASSAGE
△U2´
WALL SIDE OF FLOW PASSAGE

FIG.6

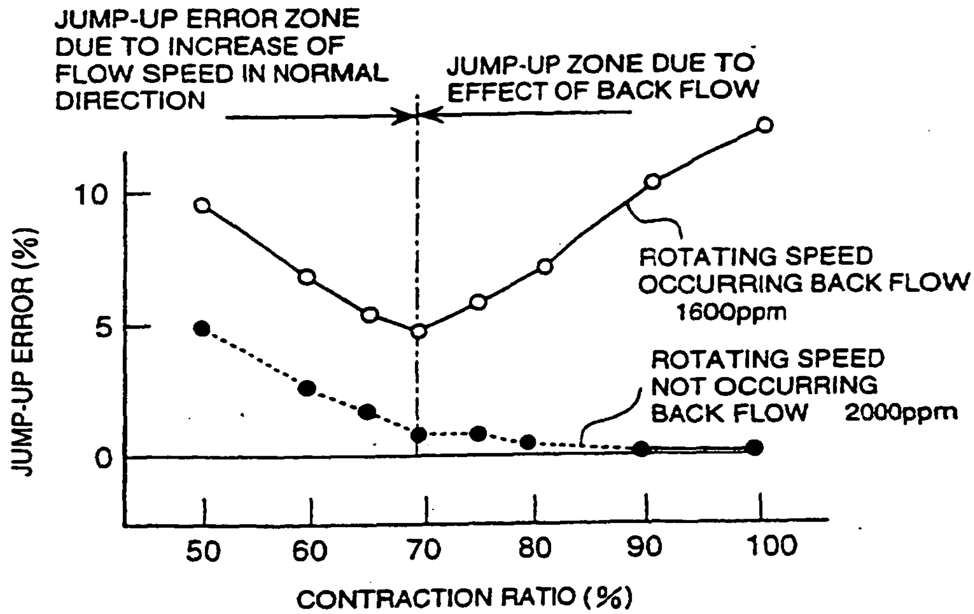

JUMP-UP ERROR ZONE DUE TO INCREASE OF FLOW SPEED IN NORMAL DIRECTION
JUMP-UP ZONE DUE TO EFFECT OF BACK FLOW
JUMP-UP ERROR (%)
10
5
0
ROTATING SPEED OCCURRING BACK FLOW 1600ppm
ROTATING SPEED NOT OCCURRING BACK FLOW 2000ppm
50
60
70
80
90
100
CONTRACTION RATIO (%)

FIG.7

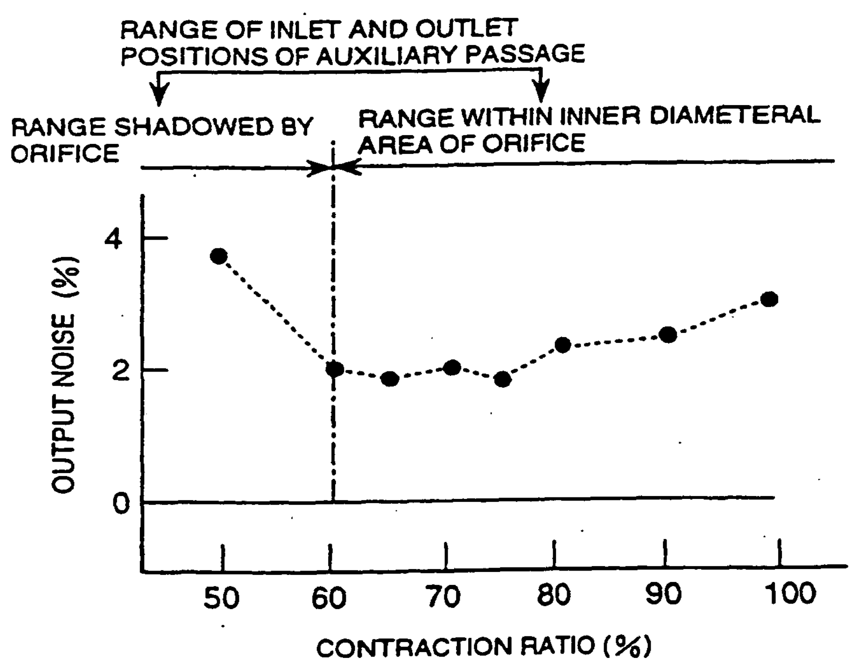

RANGE OF INLET AND OUTLET POSITIONS OF AUXILIARY PASSAGE
RANGE SHADOWED BY ORIFICE
RANGE WITHIN INNER DIAMETERAL AREA OF ORIFICE
OUTPUT NOISE (%)
4
2
0
50
60
70
80
90
100
CONTRACTION RATIO (%)

FIG.8

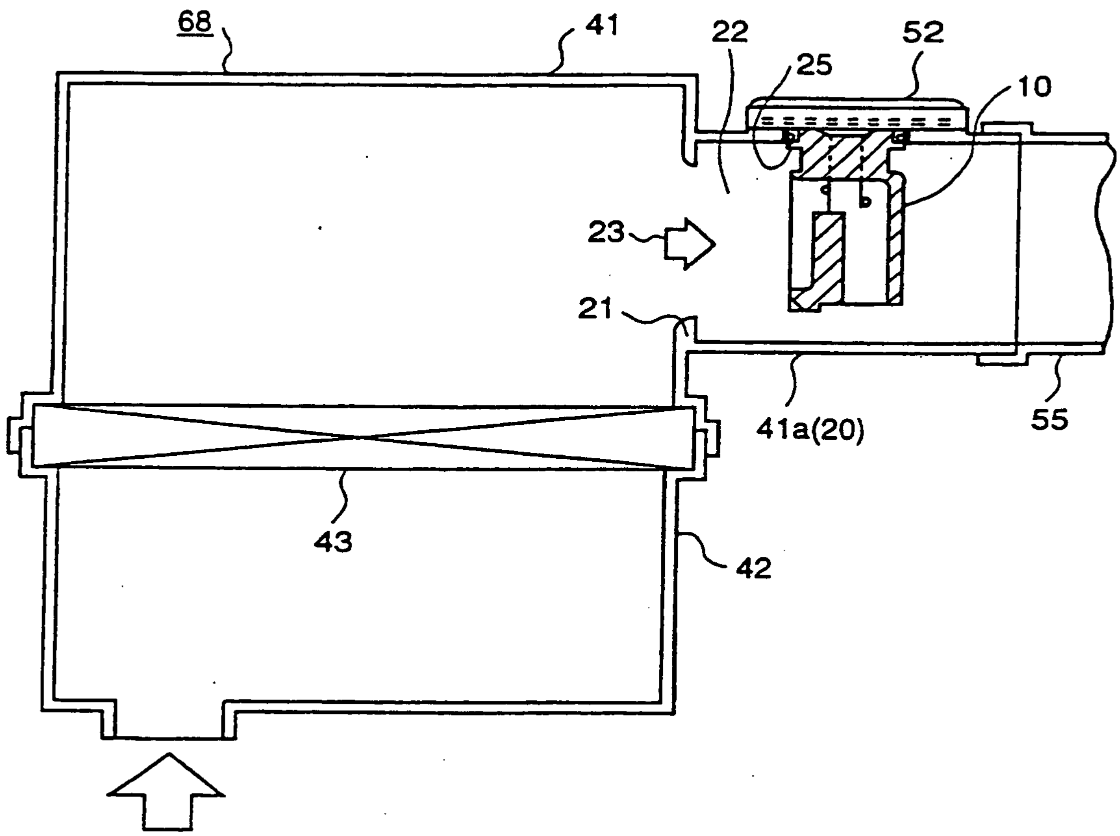


FIG.9

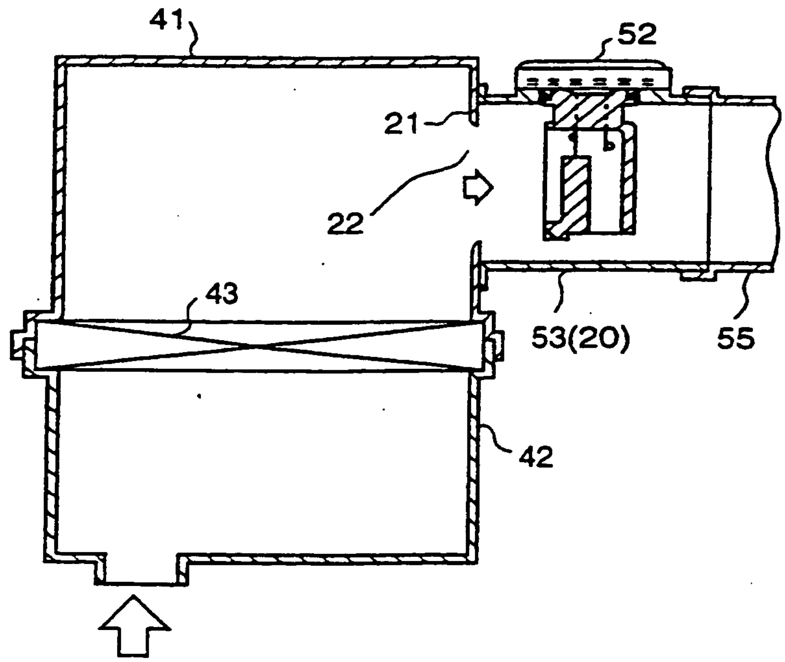


FIG.10

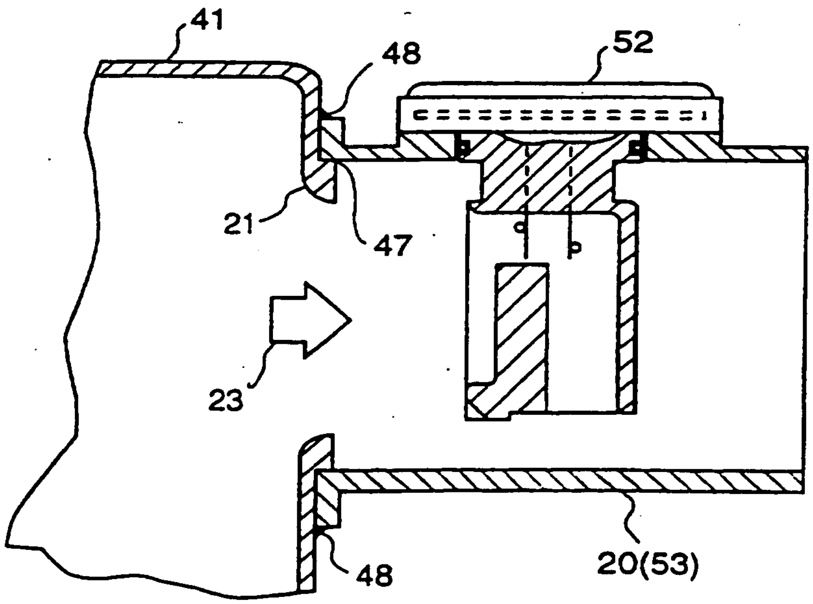


FIG.11

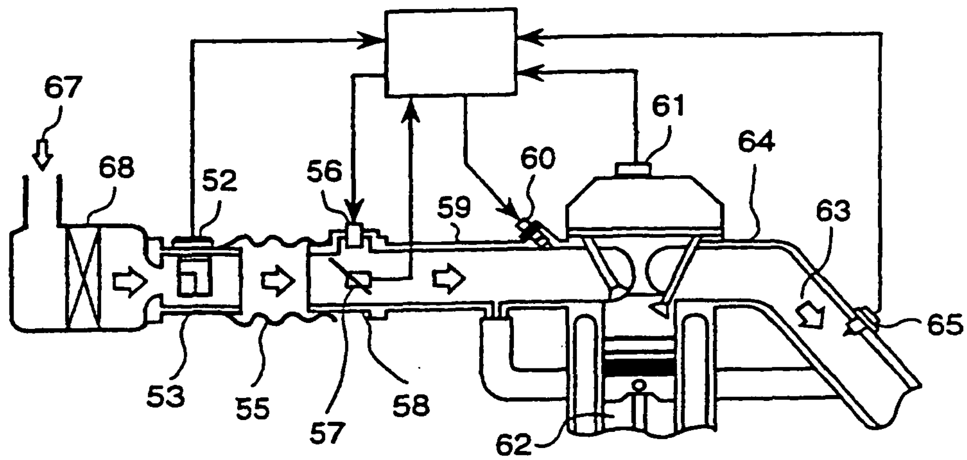

67
68
52
56
59
60
61
64
63
65
53
55
57
58
62

FIG.13

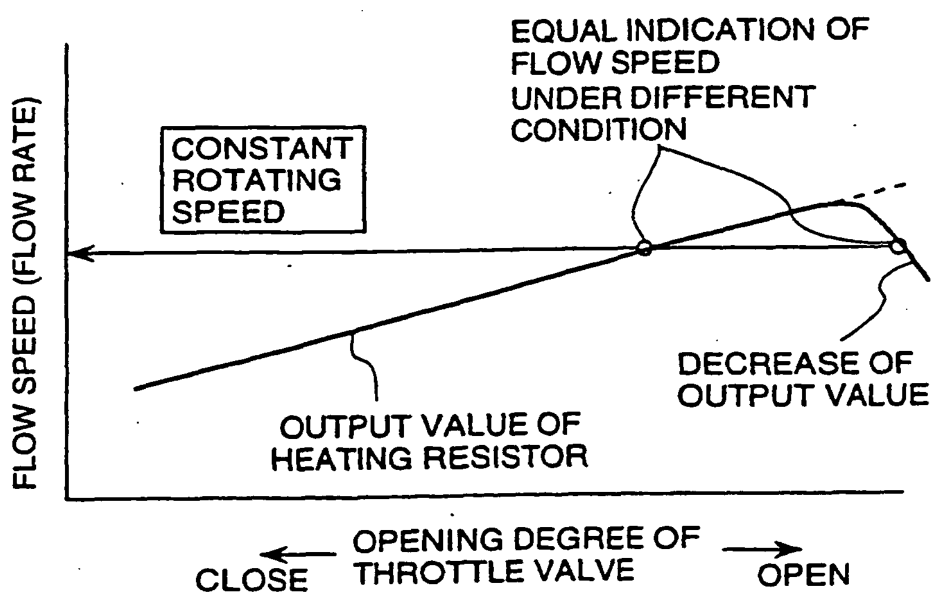

EQUAL INDICATION OF FLOW SPEED UNDER DIFFERENT CONDITION
CONSTANT ROTATING SPEED
FLOW SPEED (FLOW RATE)
DECREASE OF OUTPUT VALUE
OUTPUT VALUE OF HEATING RESISTOR
CLOSE
OPENING DEGREE OF THROTTLE VALVE
OPEN

FIG. 12A

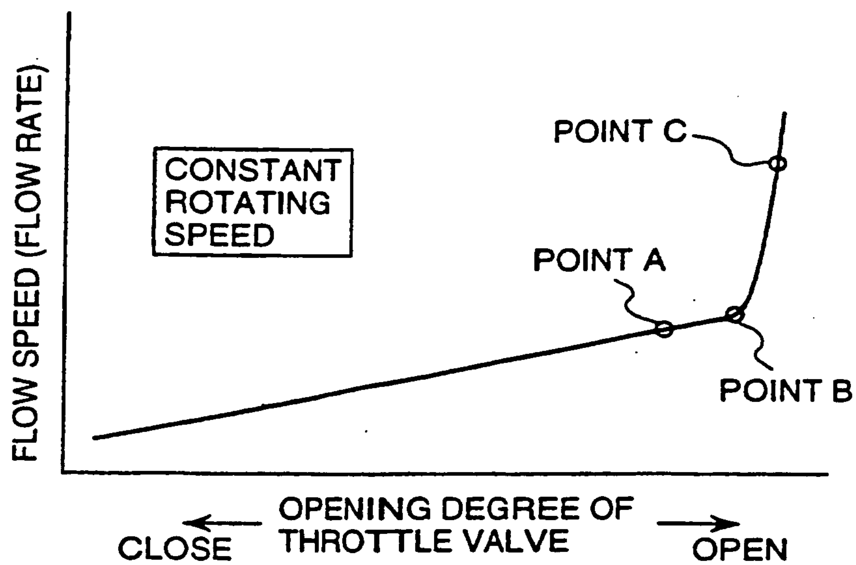
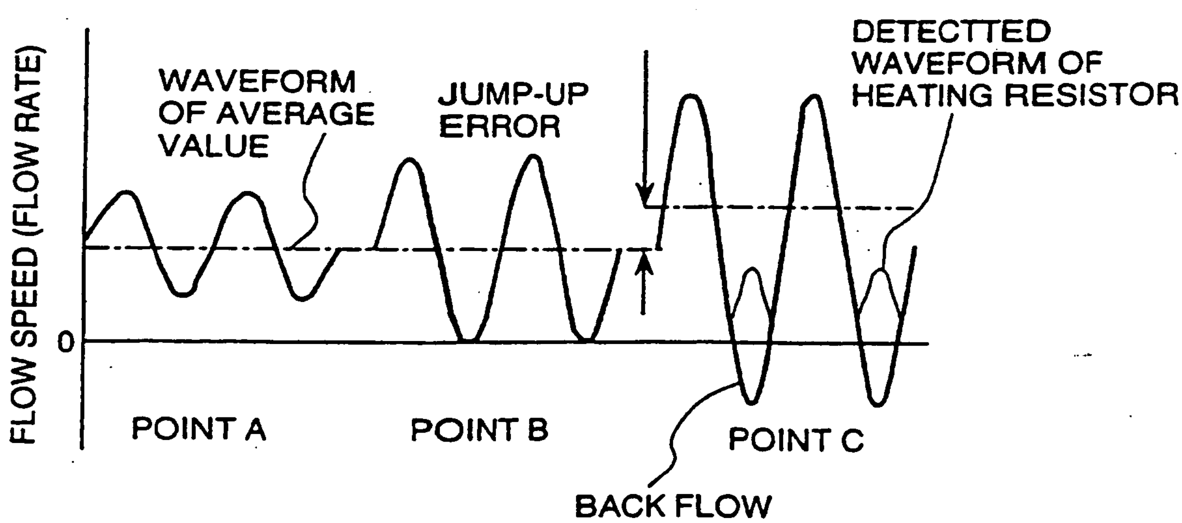


FIG. 12B



HEATING RESISTOR TYPE AIR FLOW METER

The present invention relates to an air flow meter for measuring an air flow rate, and more particularly relates to a heating resistor type air flow meter suitable for measuring an intake air flow rate of an internal combustion engine of a vehicle.

The prior art of improving the measuring accuracy of a heating resistor type air flow meter used in an internal combustion engine under a pulsating flow condition, as disclosed in Japanese Patent Application Laid-Open No.2-1518, proposes to provide a structure of flow passage having an L-shaped detecting tube. That is, the flow passage comprises a wall against backward flow so that the back flow does not directly hit on the heating resistor. Although a construction of flow passage cannot suppress back flow, it is possible to moderate a so-called binary-value phenomenon, that is, decrease of a detected value in the heating resistor type air flow meter which is caused when a pulsation amplitude of air flow increases.

Further, a construction of flow passage having an orifice is disclosed in Japanese Patent Application Laid-Open No.1-110220. In this construction, a heating resistor is arranged just downstream of an orifice inside a

detecting tube which is a nearly straight and short tube directed in parallel to the main flow direction.

In the prior art described above, it is impossible to measure flow speed by identifying direction of the flow. Therefore, when averaged output signals of the heating resistor type air flow meter are plotted as the boost pressure is being varied by gradually opening the throttle valve while rotating speed of the engine is kept constant, the averaged output signal gradually increases, but shows a jump-up phenomenon at boost pressures above a certain point indicating a plus side measuring error to an actual flow speed (flow rate), as shown in FIG. 12. The phenomenon is caused by that the amplitude of pulsation of the heating resistor type air flow meter gradually increases as opening degree of the throttle valve is increased and finally back flow occurs at opening degrees of the throttle valve above a point B, as shown in FIG. 12 (b). The heating resistor type air flow meter cannot identify direction of the flow. Therefore, when back flow occurs, the averaged output increases because flow speed is equally detected independently of forward flow and back flow. It is known that this phenomenon often occurs particularly in an engine having number of cylinders not more than four at a comparatively low rotating speed range of 1000 to 2000 rpm, and hardly occurs in an engine having number of cylinders more than four.

It is possibl to reduce the error caused by back flow

by employing one of the prior art described above in which a wall against backward flow is provided in the flow passage so that the back flow does not directly hit on the heating resistor. However, the error can be reduced by only a half. This is because when back flow occurs, forward flow increases by an amount of the back flow at the same time.

Further, it is difficult to prevent the back flow in an intake flow passage from occurring because of structures of the engine and the intake flow passage. Accordingly, in order to reduce the error caused by back flow, it is necessary to employ a complex method such as a structure in which an amount of back flow rate is subtracted from an amount of forward flow rate or a structure in which both of a forward flow rate and a back flow rate are separately measured.

Preferably, the present invention provides a low-cost and easy-to-handle heating resistor type flow meter by improving the measuring accuracy, including deviation accuracy, under pulsating flow accompanying back flow when the heating resistor type flow meter is mounted on a vehicle.

A heating resistor type flow meter according to an aspect of the invention comprises a main air flow passage body forming a main air flow passage for allowing a fluid to be measured flowing therethrough; and a measuring module having a

heating resistor for measuring a flow rate of the fluid to be measured, inserted inside the main air flow passage body, wherein

the measuring module comprises the heating resistor inside an auxiliary air flow passage body forming an L-shaped auxiliary air flow passage having an inlet opening portion opening in a direction perpendicular to a main flow line of the fluid to be measured and an outlet opening portion opening in a direction parallel to the main flow line;

the main air flow passage body comprises an orifice on a periphery of the inner side wall positioned in an upstream side of the air flow passage body; and both of the inlet opening portion and the outlet opening portion are arranged within a flow flux zone formed by extending the fluid to be measured from a top edge of the orifice in a direction parallel to the main flow line.

According to the present invention, since increase of flow speed within the flow flux zone formed by the orifice reduces an effect of back flow flowing in the auxiliary air flow passage body having the both opening portions arranged within the flow flux zone, the measuring accuracy can be improved.

FIG. 1 is a cross-sectional front view showing an embodiment of a heating resistor type air flow meter in

accordance with the present invention.

FIG. 2 is a side view showing the heating resistor type air flow meter of FIG. 1 seeing from the upstream side.

FIG. 3 is a circuit diagram showing the construction of the heating resistor type air flow meter of FIG. 1.

FIGS. 4(a), 4(B) are diagrams showing the mechanism reducing a jump-up error by an orifice in accordance with the present invention.

FIG. 5 is a view showing the mechanism reducing a binary-value phenomenon by an orifice in accordance with the present invention.

FIG. 6 is a graph showing the relationship between dimension of orifice and jump-up error.

FIG. 7 is a graph showing the relationship between position of an orifice relative to inlet and outlet ports of an auxiliary air passage and output noise.

FIG. 8 is a cross-sectional view showing another embodiment of a heating resistor type air flow meter in accordance with the present invention.

FIG. 9 is a cross-sectional view showing a further embodiment of a heating resistor type air flow meter in accordance with the present invention.

FIG. 10 is an enlarged view showing a joint portion of FIG. 9.

FIG. 11 is a view showing an embodiment of an internal combustion engine of an electronic fuel injection control type mounting a flow meter in accordance with the present

invention.

FIGs. 12(A), 12(B) are diagrams explaining a jump-up error of a flow meter under pulsating flow.

FIG. 13 is a diagram explaining a binary-value phenomenon of a flow meter under pulsating flow.

Embodiments of the present invention will be described in detail below, referring to FIG. 1 to FIG. 11.

FIG. 1 is a cross-sectional front view showing an embodiment of a heating resistor type air flow meter in accordance with the present invention. FIG. 2 is a side view showing the heating resistor type air flow meter of FIG. 1 seeing from the upstream side. Description will be made referring to FIG. 1 and FIG. 2 together.

The heating resistor type air flow meter (hereinafter referred to as "flow meter") comprises a measuring module 52 for measuring flow rate, a body 53, that is, a main air flow passage body 20, and parts for attaching the body 53 to the measuring module 52 such as screws 54a, a seal 54b and so on which form a main air flow passage 22.

A hole 25 is bored on a wall of the main air flow passage body 20 of the body 53 forming the main air flow passage 22, and the measuring module 52 of an auxiliary air flow passage body 10 is inserted through the hole 25 and fixed to the main air flow passage body 20 using the screws 54a so as to maintain mechanical strength between a

mounting surface of the main air flow passage 20 and a mounting surface of a housing 1. The seal 54b is attached between the measuring module 52 and the body 53 of the main air flow passage body 20 to keep air-tightness.

The measuring module 52 is mainly composed of the housing 1 containing a circuit board 2 for mounting a drive circuit to be described later and the auxiliary air flow passage body 10 made of a non-conductive material. In the auxiliary air flow passage body 10, a heating resistor 3 for detecting an air flow rate and a temperature-sensing resistor 4 for compensating intake air temperature are arranged so as to be electrically connected to the circuit board 2 through a support body 5 made of a conductive material. That is, the housing 1, the circuit board 2, the heating resistor 3, the temperature-sensing resistor 4, the auxiliary air flow passage 10 and so on are integrated in a unit as the measuring module 52.

In regard to the operational principle of flow measurement in the above-mentioned flow meter, the construction of circuit will be described first. FIG. 3 is a circuit diagram showing the construction of the heating resistor type air flow meter of FIG. 1. The drive circuit formed on the circuit board 2 of the flow meter is composed of roughly a bridge circuit and a feedback circuit. The bridge circuit is constructed by the heating resistor 4 (RH) for measuring an intake air flow rate, the temperature-sensing resistor 4 (RC) for compensating intake

air temperature and resistors R10 and R11, and heating current Ih is conducted to the heating resistor RH being controlled by feedback using an operation amplifier OP1 so as to keep a constant temperature difference between the heating resistor RH and the temperature-sensing resistor RC to output an output signal V2 corresponding to an air flow rate. When the air flow speed is fast, the heating current Ih is increased since an amount of heat dissipated from the heating resistor RH is large. On the other hand, when the air flow speed is slow, the heating current may be small since an amount of heat dissipated from the heating resistor RH is small. Therein, since the amount of heat dissipated from the heating resistor RH is independent of the direction of air flow, that is, forward flow or back flow, the heating current Ih flows even when air flows backward and as a result the jump-up phenomenon of the flow meter occurs.

Structure characterizing the present invention will be described below, referring to FIG. 1 and FIG. 2 again. The auxiliary air flow passage body 10 of a "passage structure forming an L-shaped detecting tube" forms a nearly L-shaped auxiliary air flow passage 13 (a longitudinal passage 13a and a lateral passage 13b which is composed of an auxiliary air passage inlet port 11 opening in a direction perpendicular to a main flow line of the forward direction 23 of air flow; the longitudinal passage 13a extending parallel to the main flow line from the auxiliary air

passage inlet port 11; the lateral passage 13b communicating with the longitudinal passage 13a and bending nearly at right angle, and extending perpendicular to the main flow line; and an auxiliary air passage outlet port 12 positioned at the rear end of the longitudinal passage 14 and opening parallel to the main flow line. In general, the heating resistors such as the heating resistor 3 and the temperature-sensing resistor 4 are arranged an inner portion of the longitudinal passage 13a.

On the other hand, the main air flow passage body 20 of the body 53 comprises an orifice 21 formed on a periphery of the inner side wall the main air flow passage body 20, positioned in an upstream side of the inserted air flow passage body 10; and the both opening portions (surfaces), the auxiliary air passage inlet port 11 of the inlet opening portion (surface) of the auxiliary air flow passage body 10 and the auxiliary air passage outlet port 12 of the outlet opening portion (surface), are arranged within a flow flux zone D formed by extending air flow 23 in the forward direction of the fluid to be measured from a top edge of the orifice 21 in a direction parallel to the main flow line (as shown in FIG. 1, the inside of the zone surrounded by the flow lines G1, G2 extending in the direction parallel to the main flow line from the top edge of the orifice 21. For instance, the flow flux zone corresponding to a cylinder having an inner diameter of D, when the main air flow passage body 20 is cylindrical as

shown in FIG. 2.).

That is, as shown in FIG. 2, shape of the main air flow passage body 20 to be inserted with the auxiliary air flow passage body 10 is nearly cylindrical (circular-tube-shaped), and an effective cross-sectional area defined by the flow flux of the air flow of the fluid to be measured flowing through the main air flow passage 22 formed the main air flow passage body 10 includes configurational positions of the inlet and outlet opening portions (the auxiliary air flow passage inlet port 11 and the auxiliary air flow passage outlet port 12) of the auxiliary air flow passage body 10.

In other words, the orifice 21 is provided in the periphery of the inner side wall the main air flow passage body 20, positioned in an upstream side of the inserted air flow passage body 10. The cross-sectional shape of the orifice 21 is a venturi-shape having its center axis nearly equal to that of the main air flow passage 22, an upstream side of the orifice 21 is nearly arc-shaped and a direction of a wall surface of the orifice 21 in the downstream side is nearly normal to the direction of the forward air flow 23. Further, in regard to the configuration of the orifice and the inlet and outlet ports of the auxiliary air flow passage inlet port 11 and the auxiliary air flow passage outlet port 12 of the auxiliary air flow passage body 10, both of the auxiliary air flow passage inlet port 11 and the auxiliary air flow passage outlet port 12 are arranged

in the inner side of the orifice diameter D (the flow flux zone D in the figure) when seeing from the upstream side, as shown in FIG. 2. It is preferable that the auxiliary air flow passage inlet port 11 is arranged at a position in the wall side of the passage and near the inner side of the flow line G1 shown in FIG. 1 and the auxiliary air flow passage outlet port 12 is arranged at a position in the wall side of the passage and near the inner side of the flow line G2 shown in FIG. 1.

The reason why the upstream side half of the orifice is formed arc-shaped (bell-mouth shaped) is that the air flow near the center of the flow passage downstream of the orifice 21 is prevented to be disturbed, and the reason why the direction of the wall surface in the downstream side half is formed nearly normal to the direction of the main flow line is that the forward air flow 23 downstream of the orifice 21 is made it easy to occur flow separation. By doing so, it is possible to increase flow speed of forward flow under pulsating flow condition downstream and inside the diameter of the orifice without disturbing the flow.

The heating resistor type flow meter in accordance with the present invention is characterized by that it comprises a main air flow passage body forming a main air flow passage for allowing a fluid to be measured flowing therethrough; and a measuring module having a heating resistor for measuring a flow rate of the fluid to be measured, inserted inside the main air flow passage body,

wherein the measuring module comprises the heating resistor inside an auxiliary air flow passage body forming an L-shaped auxiliary air flow passage having an inlet opening portion opening in a direction perpendicular to a main flow line of the fluid to be measured and an outlet opening portion opening in a direction parallel to the main flow line; the main air flow passage body comprises an orifice on a periphery of the inner side wall positioned in an upstream side of the air flow passage body; and both of the inlet opening portion and the outlet opening portion are arranged within a flow flux zone formed by extending the fluid to be measured from a top edge of the orifice in a direction parallel to the main flow line.

Description will be made below on the mechanism that the jump-up error and the binary-value phenomenon caused by the effect of back flow can be reduced by the structure of providing the orifice in the upstream side of the L-shaped auxiliary air flow passage body which is a characteristic of the present invention. Initially, comparison of effects of presence and absence of the orifice will be described, referring to FIGS. 4(a), 4(b) and FIG. 5.

FIGS. 4(a), 4(b) are diagrams showing the mechanism reducing a jump-up error by an orifice in accordance with the present invention. FIG. 5 is a view showing the mechanism reducing a binary-value phenomenon by an orifice in accordance with the present invention.

FIG. 4 (a) and FIG. 4 (b) show waveforms for cases

without orifice and with orifice, respectively. In a case of a conventional flow meter without orifice, when back flow occurs in the main air flow passage as shown by the waveform of FIG. 4 (a), the waveform of an actually detected signal becomes a waveform folded at a line nearly zero flow speed as shown by hatching lines in the figure since the flow direction cannot be detected solely by the heating resistor. Further, by employing the L-shaped auxiliary air flow passage described above, it is possible to prevent back flow from entering into the auxiliary air flow passage as shown by the waveform of effect of auxiliary air flow passage of FIG. 4 (a).

Furthermore, when an amplitude of flow speed is large enough to cause back flow at an average flow speed of U1 in the case without orifice, it is possible to prevent back flow from entering into the auxiliary air flow passage by the effect of auxiliary air flow passage. However, an average value of a waveform taking response time lag of the heating resistor into consideration is increased by Δ U1 since an amount corresponding to back flow is not subtracted from the average value and accordingly the forward flow is increased by the corresponding amount. The value ΔU1 is a detected error due to back flow.

On the other hand, in a case of arranging an orifice in the upstream side of the L-shaped auxiliary air flow passage, since flow separation eddies are generated in the downstream side of the orifice, the effective cross-

sectional area of the main air flow passage is narrowed, the average flow speed U2 becomes faster than U1 and the pulsating amplitude is also increased in the portion of arranging the auxiliary air flow passage. However, since as to the back flow there is no means for reducing effective cross-sectional area in the portion of the auxiliary air flow passage, that is, the orifice in the upstream side of the auxiliary air flow passage is not related to the back flow, the values $\Delta U1$ and $\Delta U2$ as the effect of back flow (flow rate of back flow) become nearly equal. That is, it is possible to increase the average flow speed solely without changing back flow rate by arranging the orifice in the upstream side of the auxiliary air flow passage.

Therefore, from the above relations, that is, $U1 < U2$, $\Delta U1 = \Delta U2$, the relation $(\Delta U1/U1) > (\Delta U2/U2)$ is satisfied, and accordingly the measuring error (jump-up error) of the flow meter due to back flow in the case of providing the orifice in the upstream side of the auxiliary air flow passage can be reduced compared to the measuring error in the case without the orifice.

On the other hand, provision of the orifice in the upstream side of the auxiliary air flow passage has another effect that it is possible to moderate a so-called binary-value phenomenon, that is, decrease of a detected value in the flow meter which is caused when a pulsation amplitude of air flow increases and even without occurrence of back flow. As shown in FIG. 13, the binary-value phenomenon is

decrease in output signal which is caused when intake back pressure is varied by gradually opening a throttle valve while rotating speed of an engine is kept constant. The reason why this phenomenon is caused is that the output characteristic of the heating resistor in regard to air flow rate (flow speed) has a non-linear relation.

When such a phenomenon occurs, a control system of an engine cannot perform an accurate fuel control because there are two different operating conditions to an equal indication value of flow rate. As having been described above in connection with the prior art, this phenomenon can be avoided to a certain degree by arranging a heating resistor inside an L-shaped auxiliary air flow passage having a bent without orifice. However, in order to moderate the binary-value phenomenon for all kinds of engines, it is necessary to optimize the shape of the auxiliary air flow passage for each kind of the engines. On the other hand, the orifice in the upstream side of the auxiliary air flow passage provided in the heating resistor type air flow meter in accordance with the present invention is effective for moderating the binary-value phenomenon for all kinds of engines. The binary-value phenomenon will be described below, referring to FIG. 5(a) and FIG. 5(b) showing flow velocity distributions for cases without orifice and with orifice, respectively.

As shown in FIG. 5(a) and FIG. 5(b), a flow distribution of air flow in a duct generally shows a

parabolic distribution in a steady state condition. However, under a pulsating flow condition, the distribution profile changes from the parabolic flow velocity distribution to a flat velocity distribution as the amplitude of flow speed is gradually increased. With comparing the flow velocity distribution by presence and absence of the orifice, the distribution in case without orifice becomes as FIG. 5(a) and the distribution in case with orifice becomes as FIG. 5(b).

Referring to FIG. 5(b), when the orifice 21 exists, air is difficult to flow in the vicinity of the wall surface of the main air flow passage 22 since the vicinity of the wall is shadowed by the orifice 21. Thereby, speed of the air flow in the other portion, that is, in the downstream portion of the zone D (for example, cylindrical portion having an inner diameter of D) of the orifice 21 is extremely increased. Further, an increased amount of flow speed is larger in a position in the wall side of the passage apart from the center the passage of the inner diameter downstream portion of the orifice 21 shown in the figure than in the center of the passage. This is the reason why the auxiliary air flow passage inlet port 11 is arranged at a position in the wall side of the passage and near the inner side of the flow line G1 and the auxiliary air flow passage outlet port 12 is arranged at a position in the wall side of the passage and near the inner side of the flow line G2.

As described above, between the increased amount of flow speed $\Delta U1'$ at a position in the wall side of the passage shown in FIG. 5(a) and the increased amount of flow speed $\Delta U2'$ at a position in the wall side of the passage shown in FIG. 5(b) there is a relation $\Delta U1' < \Delta U2'$. Therefore, by arranging the inlet port and the outlet port of the auxiliary air flow passage in the downstream portion of the zone D, flow speed of air flowing in the auxiliary air flow passage is also increased as an amplitude of pulsation increases. Therefore, even if an output of the heating resistor is decreased due to the non-linearity, the increased amount of flow speed increasing the flow speed flowing in the auxiliary air flow passage can compensates the corresponding decreasing amount.

However, when the dimension (inner diameter D) of the orifice is reduced too small, the increased amount of flow speed becomes excessively large and consequently there occurs a phenomenon that the output of the heating resistor increases regardless of absence of occurrence of back flow. Therefore, in taking it into consideration to decrease the effect of back flow and to reducing the binary-value phenomenon, a ratio of the effective cross-sectional area A1 of the main air flow passage 20 to the effective cross-sectional area A2 of the orifice 21 (the effective cross-sectional area of the zone D) should be set to an optimum value to be described later.

Since the effect of increasing flow speed described

above is large at a position where flow speed is large, it is important that the inlet port and the outlet port of the auxiliary air flow passage are arranged in a downstream portion inside the zone D (for example, cylindrical portion having a diameter D) of the orifice 21. That is, it is necessary that the inlet port 11 of the auxiliary air flow passage opening nearly normal to the direction of the main flow line of the air flow should be arranged in such a configuration that kinetic pressure directly acts on the inlet port 11, and the outlet port 12 of the auxiliary air flow passage opening nearly parallel to the direction of the main flow line of the air flow should be arranged in such a configuration that sucking effect in the outlet port is increased by giving kinetic pressure in the upstream side of the outlet port and generating flow separation eddies.

Further, since the outlet port 12 of the auxiliary air flow passage opens nearly parallel to the direction of the main flow line of the air flow, it is required to suppress loss by collision of air flow to the wall surface of the main air flow passage body 20. Therefore, the outlet port 12 of the auxiliary air flow passage should be arranged appropriately apart from the wall surface.

Results of an experimental study on the above-mentioned orifice dimension using a actual vehicle will be described below, referring to FIG. 6 and FIG. 7.

FIG. 6 is a graph showing the relationship between

dimension of orifice and jump-up error. FIG. 7 is a graph showing the relationship between position of an orifice relative to inlet and outlet ports of an auxiliary air passage and output nose.

A test was conducted using an engine on a bench in the same procedure as in FIGS.12(A),12(B) by gradually opening the throttle valve while keeping rotating speed of the engine and an detected error indicating the heating resistor at full open state of the throttle valve was plotted with varying dimension (inner diameter D) of the orifice. From the test, in regard to dimension of the orifice as shown in FIG. 5 (b) and FIG. 6, an effect of reducing the jump-up error due to back flow could be obtained in a range of the contraction ratio $R = (A2/A1) \geqq 70\%$, where A1 is the effective cross-sectional area of the main air flow passage in which the auxiliary air flow passage was placed, and A2 is the effective cross-sectional area of the orifice having an inner diameter of D.

On the other hand, when the contraction ratio R was smaller than 70%, it was found that the output was turned to increase. The reason is that the detected flow speed itself increases downstream of the orifice when the amplitude of the pulsating flow increases, as described above. A test result at a rotating speed not occurring back flow is also shown in the figure for purpose of reference. It was confirmed that the output rapidly increases in the range of the contraction ratio $R < 70\%$.

Therefore, it may be preferable that the ratio of the cross-sectional area A2 of the orifice to the cross-sectional area A1 of the main air flow passage in which the auxiliary air flow passage was placed satisfies the relation $R = (A2/A1) \geqq 70\%$. However, in taking the case of the contraction ratio R of 100% (corresponding to the conventional technology) into consideration, it can be said that the range $90\% \geqq R \geqq 70\%$ is preferable. Particularly, in order to reduce the error to one-half, the range $80\% \geqq R \geqq 70\%$ is preferable. Further, it has been confirmed from the test result that the effect of reducing the jump-up error is good when $90\% \geqq R \geqq 70\%$ and a distance L from the orifice 21 to the inlet opening portion 11, shown in FIG. 1, is near a value satisfying the relation $L = 0.7D$.

Description will be made below on the relationship between positional relationship of the orifice and the inlet and outlet ports of the auxiliary air flow passage and output noise of the flow meter under a steady state condition, referring to FIG. 7. In FIG. 7, the ordinate indicates value of output noise and the abscissa indicates contraction ratio R as the same as in FIG. 6.

Dimension of a sample orifice used in this test had a contraction ratio R of nearly 60%. Therefore, a contraction ratio R in the range smaller than 60% means that the both positions of the inlet port and outlet port of the auxiliary air flow passage are within a zone shadowed by the orifice 21 (a wall side zone outside a zone surrounded

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UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G1N-NACDT, NAGB2, NAGC2, NAGD2

Int Cl (Ed.6): G01F-1/69

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2285512 A	(FORD) e.g. Figure 3	
A	EP 0588626 A2	(HITACHI) e.g. Figure 1	

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